IBM Technical Disclosure Bulletin vol. 35, p. 443-445 (1992).

High Power Laser Diode with Self Adjusted Thermal Lateral Mode Control.

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This article describes a solution to the lateral mode control problem of high power laser diodes by using a special laser design which automatically corrects refractive index profile changes caused by temperature gradients occurring at high output power levels.

High power laser diodes for, e.g., optical storage applications, need to operate in the fundamental mode to ensure beam stability and the possibility of diffraction-limited focussing of the laser beam. At the same time the lasers should offer the highest possible optical output power in that fundamental mode. Unfortunately, experiments always reveal that for lasers with a weak lateral guiding, e.g., ridge, rib or stripe geometry lasers, lasing no longer occurs in the fundamental lateral mode if a certain power limit is exceeded. This power limit depends on the laser design. Our theoretical and experimental analyses of this mode control problem show that lateral temperature differences in such laser diodes are the main cause for mode instability. In more detail, the lateral mode is determined by the effective refractive index profile in the lateral direction. The ohmic heating of the laser diode by the injected electron current causes an increase of the effective refractive index of the laser diode in its center region proportional to the corresponding increase in temperature. If this increase in guiding is large enough, it changes a laser with only one allowed lateral mode (i.e., the fundamental mode) into one with two or even more allowed lateral modes. The mode stability or mode control problem of high power laser diodes is therefore equivalent to the problem of avoiding large temperature differences in the gain bearing region of the laser diode cross-section.

To avoid large temperature differences in or close to the gain bearing region we introduce additional ohmic heat sources at each side of the lateral confinement structure, i.e., at the sides of the ridge for a ridge laser. Originally, the gain bearing region is also the dominating heat source in a laser diode since both, gain and temperature, are caused by the injected electron current. By adding the additional heat sources, we increase the temperature in those regions neighboring the gain bearing region until the temperature profile is nearly flat in a large region with the gain bearing region at its lateral center. In principle, there are two classes of thermal heating inside a laser. Firstly, there is the ohmic eating described by POhm = RserI2 which relates the thermal power to the serial resistance and the drive current. Secondly, there are several heating processes, all directly proportional to the drive current. Because of the quadratic increase of the ohmic losses with drive current, it is found that ohmic losses dominate at those high power values where the mode stability problem occurs. Hence, one can make the new laser self-adjusting by connecting the new ohmic heat sources and the laser itself in series. This means that for a given laser, in a large range of high power values, the temperature increase in the gain bearing region can be compensated by a corresponding temperature increase in the neighboring regions, if the position, width and perhaps material of the additional heat sources are chosen properly. Hence, this temperature compensation scheme for avoiding lateral temperature differences in or close to the gain bearing region will work over a large range of high optical power levels.

The figure shows an example geometry for our new laser design based on a ridge laser structure 1. By adding a some-micrometer-wide metal plating 2 along the cavity, insulated by a thin SiO2 layer 3 (or any other suitable insulator) from the laser, it should be no problem to build an ohmic heat source capable of reducing the temperature differences. It is likely that one has to add more than one additional heat source on each side of the ridge 4 (or generally on each side of the lateral confinement structure) to achieve a flat temperature profile. The heat source farthest away from the lateral center must be the strongest while that closest to it must be the weakest.

Another possibility may be just to use one single heat source with non-uniform heat generation. This may be realized by a metal plating where the thickness of the metal layer (=heat source) varies with distance from the lateral center of the laser. The additional heating of the junction region should be significantly smaller than the heating already present in the old structure. But, if the additional heating should be a problem for the laser facets, it is not necessary to extend the additional heat sources up to the facets. It is sufficient if a large region along the laser cavity is single mode. Even if the cavity becomes multi-mode in some region (e.g., the facets), the single-mode region would act as a mode filter and thereby sustain single-mode behavior of the laser.

Diagrams: